1.5 Portable Acoustic Wave Sensor Systems for Volatile Organic Compounds

Technology Need

Many DOE sites have been contaminated with VOCs, such as carbon tetrachloride at the Hanford Site, and trichloroethylene (TCE) found at the Savannah River Site. In addition, there are a large number of non-DOE sites that have also been contaminated with VOCs. To characterize this contamination, sensors are needed that can provide rapid field screening before, during, and after remediation processes. Systems are also needed for real time, on-line monitoring of contamination levels in process streams during the remediation. For example, monitoring of VOCs in off-gas streams during soil vapor extraction operations can help to document the effectiveness of the remediation and to optimize its performance. Finally, sensors that can be used for in situ monitoring can alleviate the many sampling problems that arise, especially with deep monitoring wells.

Technology Description

The portable acoustic wave sensor (PAWS) technology consists of one or more surface acoustic wave (SAW) sensors utilizing sorbent coatings to detect chlorinated hydrocarbons (CHCs) and other VOCs as shown in Figure 1.5-1. By measuring the velocity and attenuation of the sensor(s) as chemical species are sorbed into the coating(s), rapid and sensitive detection can be achieved. As described in more detail below, this project is being performed in collaboration with three U.S. companies: Sawtek, Inc.; General Atomics; and, Nomadics, Inc.; as well as with Pacific Northwest National Laboratory (PNNL). This collaborative project involves designing, developing, and field-demonstrating a versatile hand-held monitoring instrument of environmental and occupational safety interest, for VOCs, including the CHCs of particular interest to DOE. These instruments will include an array of coated SAW sensors, environmental sampling and pretreatment systems, analog and digital electronics, microprocessors, and data analysis software. The systems will be designed to provide rapid, real-time monitoring of one or more VOCs with detection levels at or below regulatory levels. Species identification will be performed using pattern recognition techniques on the multiple responses from the sensor array. For more information on SAW sensor arrays and pattern recognition techniques, see the companion report in this volume on "Surface Acoustic Wave Array Detectors".

Figure 1.5-1 Schematic of a surface acoustic wave sensor with an on-chip temperature probe (RTD) for temperature control and compensation.

Current project activities are focused in three main areas. The first task involves developing and demonstrating environmental sampling systems using preconcentrators and semi-permeable membranes that will increase the versatility and ruggedness of the PAWS technology. Sensing capabilities are being extended to provide lower detection levels (about a factor of 100 lower), an improved resistance to interfering chemicals, and an ability to provide rapid, field analysis of water samples. Issues such as chemical compatibility, speed of analysis, and power requirements are being considered in this development.

The second task involves developing and fabricating an initial SAW array prototype system to be field tested this year to demonstrate capabilities and provide insight into key areas for improvement. This work involves various hardware components including analog drive electronics and multiplexers for the SAW array; data acquisition and control electronics; relays for activating pneumatic components; and batteries, power supplies and converters. In addition, software is being developed to operate the system, take the relevant SAW array responses, and present the results.

The final task involves providing technical assistance and advice to various project collaborators based on our extensive experience in developing, fabricating, and field testing environmental monitoring systems based on SAW sensors. Part of this work involves limited testing of coated SAW sensors to validate and expand on the main characterization effort at PNNL.

Benefits

PAWS can perform continuous, on-line or in situ, monitoring with rapid and reversible response. In comparison to off-site analysis of grab samples, PAWS performs real-time monitoring, a key benefit when conducting remediation activities. The systems are small, portable, and easy to set up and use. Combined with the low system cost, the low operating costs make the PAWS technology much less expensive. The sensor can be configured so that it can be placed downhole for in situ monitoring and can be automated to provide chemical information to site remediation workers. Current PAWS systems have capabilities for determining molecular species and concentrations of isolated chemicals. Systems under development by this collaborative team will be able to analyze multiple species in mixtures in either air or water. Detection levels will be at or below typical regulatory action levels. PAWS is fast, cheap, and as safe as currently available alternatives, such as gas chromatographs or infrared analyzers.

Collaboration/Technology Transfer

This project is being performed in collaboration with three U.S. companies and PNNL. The companies are providing significant development resources and will be the avenue for commercializing the technology. This collaborative program was established based on a Commercialization Plan executed by the Principal Investigator (PI). The names and roles of the various industrial parties are: (1) Sawtek, Inc., a leading supplier of SAW devices, is developing and will be a commercial supplier of the SAW array assembly, including the SAW sensors with appropriate polymer coatings, a test fixture with gas sampling ports, temperature control and compensation circuitry, and SAW drive electronics, (2) General Atomics is responsible for networking hardware for application of these systems at environmental sites, and (3) Nomadics, Inc. is designing and developing PCMCIA-based data acquisition and control electronics compatible with the SAW array systems being developed, along with Windows-based software for system control and data acquisition and analysis. The role of PNNL is described in a separate report in this volume, titled "Surface Acoustic Wave Array Detectors." As a result of this collaborative team effort, a SAW array system for VOCs should be commercially available in 1997.

Accomplishments

- A small PAWS module as shown in figure 1.5-2 with an adsorbent preconcentrator was fabricated and interfaced with a PCMCIA data acquisition and control card from Nomadics, Inc. Laboratory tests demonstrated quantitative analysis of trichloroethylene (TCE) in air from less than 100 ppb to over 200 ppm. In conjunction with Nomadics, this system was demonstrated at Tinker Air Force Base for detection of TCE in air in process

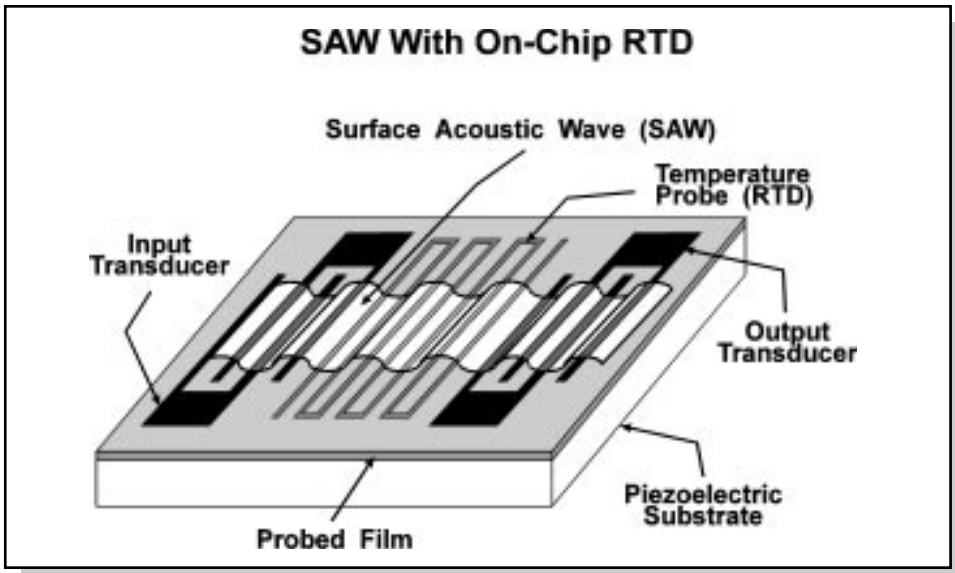

Figure 1.5-2 Picture of a small single SAW sensor module with an adsorbent preconcentrator for trace detection of isolated VOCs in air and water.

streams at a water treatment facility. Water analysis capabilities were also demonstrated.

- Using adsorbent preconcentrators, detection of key VOCs in air was demonstrated at levels below 100 ppb. Detection of sub-ppm levels of TCE and carbon tetrachloride in corrosive streams containing up to 4000 ppm of Hydrochloric Acid vapor (relevant for monitoring exhaust from on-site destruction systems for CHCs) was also demonstrated. A variety of adsorbents have been evaluated for key VOCs to optimize selection for specific applications.
- Demonstrated water analysis using purge-and-trap type systems with current detection limits for typical VOCs down to the 5-50 ppb range as shown in Figure 1.5-3.
- Components for the SAW array system have been developed, including a small (58mm on a side), low power (30 mA) data acquisition and control card with full capabilities, software for operating this card to control the system and to acquire SAW response data, and a relay card for actuation of pneumatic components. A miniaturized version of a patent pending SAW drive circuit is being fabricated along with multiplexers for operating up to eight SAW sensors.
- A bench-top PAWS system using a single SAW sensor was developed for real-time, on-line monitoring of isolated VOCs. This system was demonstrated at both Hanford and Savannah River for monitoring of VOCs in off-gas streams, from soil vapor extractions systems, and samples pulled to the surface from a cone penetrometer probe. The system was shown to be easy to set up and use, and demonstrated its ability to provide rapid and accurate analysis.

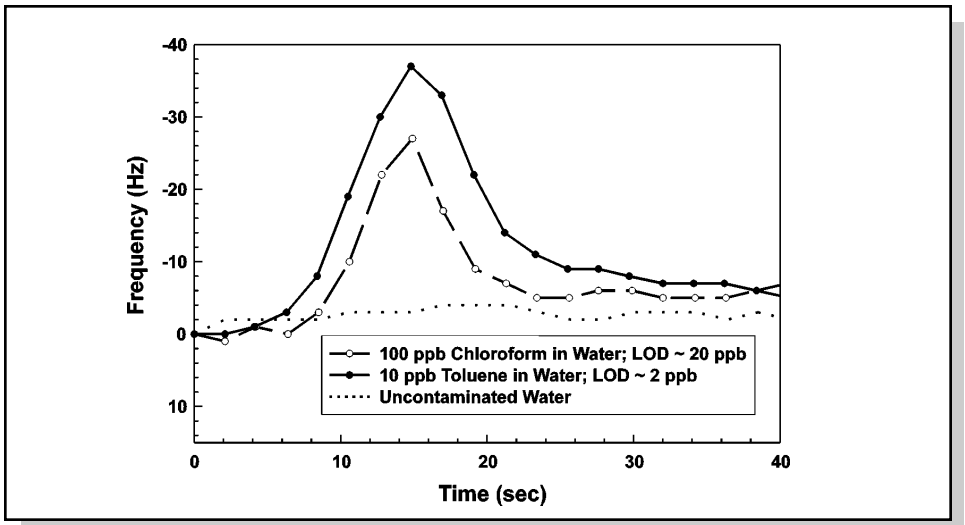

Figure 1.5-3 Response of poly(isobutylene)-coated SAW device during thermal desorption of an adsorbent preconcentrator loaded by purging water samples for one minute (total cycle time three minutes). The small response to no water, compared with the responses with trace amounts of VOCs, demonstrates the current capabilities for water analysis.

- A downhole PAWS system (single SAW sensor) with associated packers was developed for in situ monitoring of isolated VOCs in vadose zone boreholes, with diameters over 4 inches. This downhole probe was demonstrated at Hanford, providing continuous in situ monitoring of carbon tetrachloride concentrations from 10 to over 20,000 ppm.

TTP Information

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Contacts

Greg Frye
Principal Investigator
Sandia National Laboratories
P.O. Box 5800, MS-1425
Albuquerque, NM 87185-1425
(505) 844-0787

Dennis Olona
Technical Program Officer
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, NM 87185-5400
(505) 845-4296

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